WEST AFRICAN COCOA RESEARCH INSTITUTE

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No. 53

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WEST AFRICAN COCOA RESEARCH INSTITUTE
TAFO, GHANA

FIFTY-THIRD QUARTERLY REPORT

JANUARY-MARCH, 1959

Any results recorded in this report should not be accepted as conclusive inasmuch as the report contains interim information only. More complete results are published in W.A.C.R.I. Technical Bulletins and elsewhere.

SENIOR STAFF

Director	J. Lamb
Deputy Director	C.G. Johnson
Scientific Assistant to Director	G.A. Jones
Secretary	H.L. Pugh (on leave 11/3/59)
Accountant	H.J.S. Mill
Assistant Accountant	J.N.A. Hyde
Office Assistant/Librarian	D.J. Ellis (Miss)
TAFO STATION	
Division of Entomology	C.G. Johnson
	E. Dunn (arrived 17/2/59)
	P.F. Entwistle
	M.R. Smith
	K.B. Armstrong
Division of Pathology	J.W. Blencowe
	A.L. Wharton
	A.A.F. Brunt
	P.D. Turner
	A. Attafuah
Division of Botany	D.R. Glendinning
	R.G. Hurd
Division of Chemistry	R.H. Kenten
	R.K. Cunningham
Division of Agronomy	R.W. Smith
Statistician	C. de Jonge
Laboratory Technicians (Electronics)	A.J.H. Arnold
(Spectrography)	J.C. Burridge
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Maintenance Engineer	A. Maddison
Works Superintendent	E.K. Berko
Guide-Demonstrator	F.E. Decker (on leave 9/1/59)
Station Manager	S.E. Ntim-Kwafo
Medical Officer	P.K.K. Knudsen
IBADAN SUB-STATION	
Deputy Director (Nigeria)	T.W. Tinsley (on leave 24/3/59)
Entomologist	R.G. Donald
	C.K.H. Martini (on leave 5/1/59)
Pathologists	J.M. Thresh (on leave 17/3/59)
	D. Kay
Agronomist	J.F. Longworth
WEST AFRICAN FUNGICIDES RESEARCH UNIT	
Mycologist	E.C. Hislop
Chemist	P.O. Park

MANAGING COMMITTEE

The twenty-sixth meeting of the Managing Committee was held at Tafo on the 5th February, 1959, and a special meeting of the Committee was held at Ibadan on the 9th March, 1959. The Technical Sub-Committee met at Tafo on the 3rd February.

STAFF MATTERS

Mr. E. Dunn arrived in February to take up his appointment as Head of the Entomology Division, in place of Dr. C.G. Johnson, who is due to return to Rothamsted Experimental Station in April. Dr. T.W. Tinsley, Deputy Director (Nigeria), Mr. H.L. Pugh, and Mr. J.M. Thresh went on leave in March, and in the same month Dr. C.K.H. Martini returned from leave.

VISITORS

The Institute was honoured by a visit from Mr. K.A. Gbedemah, Minister of Finance, in January. A U.K. Parliamentary Delegation to Ghana called at the Station in February.

A number of delegates to the first F.A.O. Technical Meeting on Cocoa in Accra visited the Institute before and after the conference. These included Dr. G.A.C. Herklots, Principal of I.C.T.A., Trinidad; Dr. A.F. Posnette, East Malling Research Station; Prof. C. Coolhaas, Wageningen; Professor Branquinho de Oliviera and Mr. M.M. Batista, Portugal; Messrs. J. Nanta, M. Delassus and R.Renaud, Ivory Coast; Dr. G. Havord and Dr. P. de T. Alvim, Interamerican Institute of Agricultural Sciences; Dr. E.P. Imle, American Cacao Research Institute; Mr. F. Hendricks, Scientific Secretary C.C.T.A./C.S.A.; Mr. L.A. Bridgland, Papua and New Guinea; Mr. B.F. Topper, Jamaica; Mr. L.L. de Verteuil, Trinidad; Mr. Van Himme, Belgian Congo; and Mr. J.T. Swarbrick, South Cameroons. Many of these delegates later visited the Sub-Station at Ibadan.

Other visitors during the quarter have included Sir Frank Engledow; Prof. P.M. Blackett; Mr. & Mrs. T.E. Mars of Mars Ltd.; Mr. K. Wilson-Jones, Pesticides Research, London; Trade Missions from the U.K., Poland and East Germany; Messrs. V. Barna and A. Brook; and Mr. B.M. Church of the Statistics Department, Rothamsted Experimental Station.

The Minister of Agriculture, Eastern Region of Nigeria, the Hon. P.O. Nwoga paid a short visit to the Sub-Station in

March. Messrs. A.V. Gibberd and P.V. Harris, Northern Region, Nigeria; Dr. Lucile Carbon, Western Reserve University, Cleveland, Ohio; Messrs. J.A. Berryhill and H. Richwine, I.C.A., Lagos; and Mr. M. de N. Ensor, F.A.M.A. also visited the Sub-Station.

FIRST F.A.O. TECHNICAL COCOA MEETING

The first F.A.O. Technical Cocoa Meeting was held in Accra from the 8th to 15th February, 1959. The Director, Mr. J. Lamb, was elected Vice-Chairman of the Meeting and Dr. C.G. Johnson chairman of the 7th Technical Session on "Experimental Design". The meeting was attended by most of the members of the senior staff, and the following papers were presented:

"Cocoa breeding in West Africa" - D.R. Glendinning.

"Shade and nutrition as limiting factors in the cultivation of cocoa in Ghana" - R.K. Cunningham.

"World survey of cocoa virus diseases" - T.W. Tinsley. Guest Speaker, 4th Technical Session.

"Black-pod and other cocoa diseases of immediate or potential importance in West Africa" - A.L. Wharton, Guest Speaker, 4th Technical Session.

"A virus disease of cocoa in Sierra Leone" - A. Attafuah and J.W. Blencowe.

"The ecological approach to cacao research in Ghana" - C.G. Johnson.

"Control of cacao swollen shoot vectors; a survey of the problem and recent advances in Ghana" - P.F. Entwistle.

"Fermentation and drying" - T.A. Rohan, Guest Speaker, 6th Technical Session (former member of WACRI staff).

"Tray fermentation of West African Amelonado Cocoa" - H.W.S. Allison and R.H. Kenten.

"Some problems in designing fertilizer field experiments on Ghana cocoa in its early years of bearing" - R.K. Cunningham and J.C. Burridge.

"Variety trial design" - D.R. Glendinning.

MANAGEMENT AND MAINTENANCE

Routine maintenance has been carried out. A new workshop for the repair and construction of laboratory equipment

has been built.

At the Ibadan Sub-Station the second Senior Staff house has been completed.

CROP DELIVERY

The number of pods harvested during the quarter is given below :

Month	Old Station	Square Mile	Total
January	87,182	34,618	121,800
February	5,101	-	5,101
March	55	-	55
Total	92,338	34,618	126,956

SWOLLEN SHOOT DISEASE

The number of trees removed during the quarter due to swollen shoot disease and other causes is given below :

Month	Trees destroyed		Total	Total Seedlings removed
	Swollen Shoot	Undiagnosed		
January	15	1	16	32
February	16	-	16	47
March	18	2	20	22
Total	49	3	52	101

UPPER AMAZON SEED

A total of 6,173 F3 Upper Amazon pods were sent to Nigeria for seed during the quarter.

METEOROLOGY

Month	1959		21-year mean	
	Rainfall (in.)	Wet days	Rainfall(in.)	Wet Days
January	0.29	2	1.54	3.8
February	2.08	5	3.59	6.9
March	9.84	13	5.89	11.9
Total	12.21	20	11.02	22.6

T A F O S T A T I O N

PATHOLOGY DIVISION

VIRUS RESEARCH

A series of field experiments has been started to study the effects of virus infection on the growth and yield of mature cacao trees. It is hoped that these experiments will give some information on the cause of death of virus-infected trees in Ghana; particular attention will be paid to the role of capsid injury in bringing about the eventual death of infected trees. The experiments fall into two groups, those in which trees are being artificially infected, and those where observations are being made on naturally occurring outbreaks of virus. The artificial inoculations are being made at W.A.C.R.I., in conditions where capsid injury is being reduced to a minimum over the total experimental area by regular treatment with insecticide. The first experiment compares trees graft-inoculated with five viruses with healthy controls. The trees are young Amelonado, just coming into bearing. The viruses tested are mild and severe swollen shoot isolates of the New Juaben type, cacao mottle-leaf virus from Kpeve, the mild isolate from Bisa that causes only swellings, and a relatively severe virus of the swollen shoot complex from Dawa in Western Ghana, (which is not immunologically related to the New Juaben isolate). The experiment is arranged in a 6 x 6 Latin Square with fourteen trees per plot. The second experiment is designed to study the effect of infection with a severe swollen shoot virus on trees grown in the presence and absence of an application of a compound fertilizer. The design is a 2^2 factorial one with each treatment combination replicated six times on plots of eight trees each. The complete experiment is itself replicated on Amazon and Amelonado cacao, each growing with and without shade, making a total of 96 plots in all. In each case the cacao is young and has recently come into bearing.

The second group of experiments studies the effect of routine capsid-spraying on the yield and growth of trees infected with swollen shoot virus. The experiments are being made with the co-operation of the Division of Agriculture, and Mr. R. West-Skinn has been appointed to co-operate in the project. The experiments will be of two kinds, some will be in places at the edge of the main area of virus spread in the Eastern Province and the treated and untreated plots will be arranged so that about

20 per cent of the trees are infected at start of treatment. It will thus be possible to observe the spread of infection and subsequent decline in vigour of the trees in the presence and absence of capsid injury. The plots will each contain about 300 trees of random-planted Amelonado cacao. About a dozen pairs of plots of this type are planned, mostly in the centre of the Eastern Province. The second type of experiment is being carried out on plots of totally infected cacao growing in remote areas of the Eastern Province and in the West of Ghana. The viruses in these cases will, of necessity, be less virulent than those in the previous group of experiments, for most of the viruses in the Eastern Province kill the trees too quickly for it to be possible to select a compact area of three hundred infected, but still living, trees.

Laboratory tests have shown that the spiny, well-buttressed Ceiba thonningii A. Chev. is susceptible to the Sierra Leone cacao virus isolate from Gandorhun. The back-tests from the seedlings showing symptoms gave a low infection rate, a difficulty that is accentuated when tests are made from growing trees. A virus of the swollen shoot complex (Yakasse), and two of the cacao mottle-leaf type (AD 75 & AD 191), have been transmitted to an herbaceous host plant, Corchorus aestuans Lam. Another cacao mottle leaf isolate (AD 14), has been transmitted to Corchorus trilocularis Linn.

Attempts to transmit virus from a Loranthus sp. (probably farmari Sprague), growing as a semi-parasite on an infected cacao tree, were unsuccessful.

Tests of the progeny of crosses made between T17 Iquitos cacao selections to discover whether they are resistant or tolerant to virus infection are continuing. In addition, the Scavina selections T12/113 and T12/27 appear to be a possible source of resistant or tolerant material.

STUDIES ON BLACK-POD DISEASE

Fungicide spray control trials

The second spray control trial (cf. Quarterly Report No.49, p.5) has been re-organised and in 1959 the effect of spray chemicals will be measured only by the wet weight of beans harvested; diseased pods, as they appear, will be left on the trees until the end of the year.

Spraying on the Pod Susceptibility Experiment has been reduced to fortnightly applications and cherelles less than two

weeks old will not be sprayed (cf. Quarterly Report No.51, p.6).

Resistance and tolerance

Field recording of diseased fruits on the 1st Clonal Trial selections has now ceased, and similar data on differential susceptibility to pod disease are being collected on the 2nd Clonal Trial, where 1 Amelonado and 19 Trinitario types are represented. Records from the 9th Progeny Trial will continue this year. The five blocks in the 2nd Progeny Trial least damaged by virus losses and poor growing conditions have been wired off and are being recorded for pod disease. Progeny of both susceptible and resistant types from the 1st Clonal Trial are included in the 2nd Progeny Trial.

Final analyses of two years' data from the 1st Clonal Trial have been completed by Mr. de Jonge and are summarized briefly below.

Selection	PODS PER TREE (1957)		PODS PER TREE (1958)	
	Total pods	Total "black pods"	Total pods	Total "black pods"
A12	24.3	15.2	43.1	5.5
A62	22.5	13.9	37.2	3.6
A73	27.4	9.2	56.0	5.7
A46	22.3	9.5	37.2	2.5
A36	26.2	7.1	46.8	3.4
SC1	20.1	7.5	23.4	1.8
K5	26.8	7.0	41.8	0.9
02	16.7	4.7	21.4	0.9
B3	19.1	2.6	31.3	0.9
S27	33.3	3.0	52.0	1.2
E17	17.7	4.5	27.4	0.6
E1	10.9	1.2	25.1	1.2
N38	16.7	1.9	29.6	0.5
S36	11.7	1.4	16.4	0.3
Y44	22.8	1.5	26.0	0.2

In this table the numbers of "black pods" should not be regarded as a proportion of the total pods, because the former figure includes cherelle infections whereas for the latter only fruits beyond the cherelle stage were counted. There is, however, a close correlation between the number of cherelle infections and

the numbers of large diseased fruits ($p < 0.001$). The data were analysed by Mr. de Jonge and the selections are presented in order of decreasing susceptibility, on the basis of the two years' combined data. Five selections from the middle range are not included, and the upper 7 selections are all significantly different from the lower 8 at $P = 0.001$.

The results form a basis for comparing the susceptibility of available progeny from these selections (2nd Progeny Trial recording) and also for a breeding programme to study further the genetic factors controlling susceptibility. It is hoped to make the appropriate pollinations in 1959 with a view to planting a specific pod disease resistance trial in 1960.

There is no close fit between the tolerance rankings of selections in the 1st Clonal Trial and the rankings for field resistance (cf. Quarterly Report No. 52, p. 7) and it is not possible to screen other selections for resistance by using the simple wound inoculation technique for measuring tolerance. All selections in the 1st Clonal and 9th Progeny Trials are now under test for tolerance to bark infection.

Detailed pod disease recording has been started on the Amelonado Spacing Trial, to study the distribution of pod disease on groups of trees whose total yield, whether measured on a per-tree basis or on a per-acre basis, covers a wide range.

Strains of Phytophthora palmivora

Further examination of the isolates collected in Ghana (Quarterly Report No. 52, p. 7) has been made. Comparison of growth rates of all isolates with that of the isolate from Tafo, following inoculation into pods, has shown one isolate (Fomena) which spreads less rapidly ($p < 0.001$). One isolate from Sierra Leone and one from Nigeria showed no difference from the Tafo isolate in growth rate, spore size or culture appearance. Another Nigerian isolate, however, was markedly less virulent - its growth-rate decreased rapidly during serial transfer on healthy pods and finally its pathogenicity was completely lost. This isolate had small spores and growth on Czapek Dox medium was very sparse unless a thiamin supplement was provided.

A number of fruits have been inoculated with all isolates but no differential pathogenicity has yet been detected. Diseased tissue of over fifty genera and species has been sampled in a search for alternate hosts of the fungus, but only one, Gmelina arborea, has been found at Tafo. The isolate from this

host is apparently identical with the cacao pathogen, and diseased fruits were found in abundance between cacao crops. A high percentage of other diseased samples was found to be infected with organisms of the Phoma type that were capable of causing rapid pod rots which at first appeared very similar to black pod.

Saprophytic survival of P. palmivora

Work on the activity of P. palmivora in soil has continued (Quarterly Report No. 51, p. 7). Strong indications have been found that the fungus is only capable of restricted development, either from spores or diseased tissue. Aqueous soil extracts failed to show any fungistatic properties, and investigations using ether extracts are proceeding. Soil survival of spores inoculated into sterile and unsterile soils under different moisture conditions is also being studied.

ENTOMOLOGY DIVISION

CAPSID STUDIES

Joint W.A.C.R.I./Division of Agriculture capsid control trials

After two full seasons field trials in the Eastern Region (with both small-scale and large-scale units) using Endrin, Dieldrin, Aldrin, Gammalin and Malathion, a sufficient mass of data has accumulated to make continuation of these trials unnecessary. Dieldrin and Malathion have been eliminated for use against capsids, the former on account of the danger of a subsequent increase in Marmara, the latter because of sub-standard control at economic dosages. In Ashanti the trials with Endrin, Aldrin and Gammalin at dosages approximately in inverse proportion to the cost (See Quarterly Report No. 50) will continue.

With both series of trials the same general picture appears, as with earlier preliminary trials in 1956 (Rep. W. Afr. Cocoa Res. Inst., 1956-57). Comparing similar dosages of toxicant Endrin is outstanding in its control, Gammalin and Aldrin being next in order of efficiency. In all trials Aldrin is consistently less effective than Gammalin but the differences between the two are very small - of the order of 3 per cent difference in the numbers of damaged trees per 1,000 trees. Aldrin has therefore been considered suitable for capsid control in Ghana, provided the retreatment is at the 2 oz. rate of application. A full account of this work will be published elsewhere.

Laboratory assessment of insecticides

Continued difficulty is being experienced in the laboratory breeding of capsids. The mass breeding technique has been interrupted owing to a seasonal decline in capsid reproduction. A colony of Dysdercus spp. (Pyrrhocoridae) is being established and preliminary indications are that this insect is sensitive over the same range of gamma-BHC concentrations as cacao capsids and is also more robust and easier to rear in the insectary. Bioassay with this insect should prove a useful cross reference in the investigations on the efficacy of various gamma-BHC formulations now being undertaken.

MEALYBUG STUDIES

Oyoko

Ant populations have shown a considerable degree of recovery during the quarter, about a third of pre-treatment numbers of active nests having become re-established. As, after the initial double Dieldrin treatment, the recovery of the mealybug population is lagging far behind that of ants and only a few farms, usually close to unsprayed food farms, were found to have trees infested with P. njalensis. Control plot populations of P. njalensis were similar to those recorded in the previous quarter.

Systemic insecticides

The preliminary tests (see Quarterly Report No. 52) continue: the emphasis is now on Rogor 40 which appears to be superior to Ekatin and Ciba 570 (now known as Dimecron). Experimental data, concerned with stem, leaf and soil applications, will be presented later.

MINOR PESTS

Cerambycidae

A new species of Tachinidae (Dexiinae), frequently recorded as an internal parasite of the larvae of Tragocephala nobilis F. and its variety castnia Thoms. at Tafo, has been described as Billaea vanemdeni Fennah (Ann. Mag. Nat. Hist., ser 13; i, p. 682, 1958). Type material is in the British Museum.

A chalcidoid egg parasite of T. nobilis var castnia has been noted at Tafo and is very similar to specimens bred from eggs received from Mayumbe, Belgian Congo. The host to the latter specimens is probably either T. nobilis var maynei Gah. or T. Guerini White. Determination of these two parasites is

awaited.

Leaf eating lepidoptera

Approximately 100 different species of leaf-eating lepidoptera have been recorded at W.A.C.R.I., although many of these are not common. Work has been mostly restricted to collection of larvae in the field and rearing these larvae in the insectary. Many species are now ready for despatch to the British Museum for identification.

BOTANY DIVISION

PLANT BREEDING AND SELECTION

Yield data for the 1958-9 season are now complete. The level of yield in all trials has again risen. In the 9th Progeny Trial, planted in 1954, the varieties have given net yields ranging from 590 lb. to 1,130 lb. per acre, with a mean of 800 lb. per acre. Disease losses ranged from 10 to 44 per cent according to variety; had these losses been avoided the yields obtained would have been from 950 lb. to 1,540 lb. per acre. The best performances were WAE11, net yield 1,130 lb., gross 1,370 lb., and WEB1, net yield 1,090 lb., gross 1,540 lb. This cocoa became five years old at the end of the season.

In the 8th Progeny Trial, planted in 1952, the potential mean yield, if diseased pods had been saved, was 930 lb. per acre. Disease losses were heavy in some varieties, but in this case probably resulted largely from pods being left long on the trees to secure sufficient for separate fermentations. WAE5 gave a potential 1,660 lb. and WBE3 1,515 lb., but these varieties are represented by only one and two 36-tree plots respectively. Six other varieties have given yields estimated at 1,000 lb. to 1,300 lb. This cacao became seven years old at the end of the season.

Yields in the 1st and 2nd Clonal Trials were also high. In the 1st Clonal Trial, planted in 1947, only three varieties out of the 20 in the trial failed to give a potential 1,000 lb. per acre, and after deducting disease losses 14 of the 20 still exceeded 1,000 lb. A12 gave a potential yield of 1,910 lb. per acre but lost 15% to black pod, ACU85 gave a potential yield of 1,800 lb., but lost about 6% giving an actual yield of 1,700 lb. In the 2nd Clonal Trial, planted in 1948, R15 gave a potential 2,125 lb. but losses were 21% which reduced the yield to 1,690 lb., while D70 with a potential 1,830 lb. lost

only 2% leaving 1,790 lb. as the actual yield.

In the Trinidad Introductions T11 has come to the fore with a potential yield of 2,680 lb. losing 7.2% to diseases to leave 2,490 lb. T6 gave a potential 2,200 lb. and T60 1,940 lb. per acre.

With the exception of the 9th Progeny Trial all these plots are receiving a basic fertilizer dressing, as recommended by the soil chemists. Shade has been progressively reduced in recent years. The 9th Progeny Trial is at present not being fertilized so that the yields of the varieties are being assessed under the equivalent of normal farmer's conditions.

In the F1-F2-F3 trial, further to the results recorded in Quarterly Report No. 52, records were taken in February 1959. The F1 generation is still leading the others but over the period November 1958 to February 1959, i.e. through the dry season, its rate of growth, as shown by stem diameters, has been less than in the F2 and F3 generations. The reason for this is unknown, but may be genetic as the F2 and F3 generations possess genes, introduced by out-pollination, that are not in the F1.

Following the experiment on seedling growth in different varieties (see Quarterly Report No. 51) a similar experiment was set up in October 1958. The first set of data, taken in January, has been studied. In four cases the seedlings of a variety were obtained from two pods, and good agreement was found between the seedlings derived from these pods. Three characters were observed, viz. stem height, stem diameter, and number of leaves. The exact relations between these characters varied from variety to variety; thus one variety had a shorter stem relative to its thickness and to the number of leaves than had the others. However, in spite of this minor variation, the order of ranking of the varieties was the same for all three characters. This ranking did not correspond especially well with that of the yields of the varieties in the 2nd Progeny Trial, one variety doing considerably better as a seedling than expected. A second set of data have been recorded, but not yet studied.

Data from the trials in Western Nigeria indicate that there are marked differences between the varieties, in the retention of leaves through the dry season, and some differences in the relations between the rates of growth in the wet season and in the dry season (as shown by stem diameters) can be detected. It should be mentioned that the primary selection of W.A.C.R.I.

varieties has been made at Tafo, where dry season conditions are not as severe as, for example, in much of Western Nigeria. Detection of drought-resistant types therefore depends upon the results of these trials.

Stem diameter measurements in the series I trials in Ghana continue to show the marked superiority of the Amazons over the local types. The Bunso trial is now in bearing, giving in the 1957-8 season an average of 23.7 pods per tree over all varieties. The Amazon varieties T60 and T17 averaged 47.3 and 29.3 pods per tree respectively; the local types TF1 and S72 10.9 and 7.4 pods. The local types are planted at a closer spacing than the Amazon types in this trial (7 ft. x 7 ft. and 10ft.x 10 ft. respectively), so that in terms of pods per acre these yields become T60 20,500, T17 12,700, TF1 9,700 and S72 6,000. T17 has larger pods than T60, so that the difference in yield between these two is less than is suggested by these figures. A peculiar feature of the data is that a marked advantage appears to be associated with the outer position in a plot, even when the plot is in the centre of the trial so that it is contiguous with other cacao. Thus if each 25-tree plot is divided into an outer guard-row of 16 trees and an inner plot of 9 trees, mean yields (pods per tree) are as follows : T60 guards 50.1, plots 42.4, T17 guards 31.4 plots 25.6, TF1 guards 11.6 plots 9.7, S72 guards 9.0 plots 4.6. The data will be studied to see if this effect continues in future years, as the trees become larger. A similar effect could not be confirmed in stem diameters.

PHYSIOLOGY OF NUTRITION AND GROWTH

Nutrient culture experiments

Leaf analyses have been carried out on the cacao seedlings which had previously shown symptoms resembling "stag's head" and "paint-brush" disease (see Quarterly Report No.52, p.12). Neither the seedlings which have been treated with supplementary nutrient solution, nor the untreated controls, are now showing abnormal symptoms. In leaves from untreated plants boron and copper concentrations were similar to those in normal healthy cacao in the field and in plants grown in complete nutrient solutions. Boron and copper concentrations were higher than normal in the seedlings treated with these elements.

In the nutrient culture experiments on induced copper and boron deficiencies it has proved impracticable to grow seedlings in deficient culture solutions from germination, and

therefore seedlings have been grown in baskets of soil until they are required for the experimental treatments. Beans of cacao variety Na3L x Pa35 were sown in baskets of soil, and three weeks later were transplanted into sand or water culture solutions. Similar seedlings will be transplanted after three and six months in soil.

Transplanted seedlings have grown less well than those left in soil, regardless of treatment. In many cases, but particularly with sand culture, there has been a suppression of apical dominance, which has led to a bushy growth habit, and even in the complete nutrient solution there has been some sickle leaf. In previous experiments seedlings have been successfully transplanted after five months in soil; very young seedlings may be less able to adapt to their new environment.

In contrast to the other treatments, seedlings transplanted to solutions deficient in boron, or in boron and copper, have not developed laterals. Growth in the boron-free solutions was poor, but there was little evidence of leaf symptoms after six weeks in the solutions. This was also true with the copper-free solutions, although some of the new leaves are showing a marginal and terminal necrosis. The unavoidable use of metal-distilled water and pyrex glassware may have complicated symptom expression. Growth in solutions free of both boron and copper was better than that in solutions deficient in only one of these elements, although not as good as in the control. With each treatment sand and water cultured plants behaved similarly

Effect of early bearing

An experiment was started in 1955 to determine the effect on cocoa of preventing early bearing. The cacao trees used came into bearing in 1955/56. Three treatments were applied:

A - Control. No restrictions on bearing

B - All flowers and pods removed until January, 1957

C - All flowers and pods removed until January, 1958.

Covariance analysis on the trunk diameters recorded over this period has shown that in June, 1957, trees receiving treatments B and C had larger girths than the controls, the difference being highly significant statistically. In December, 1958 the girths of trees under A and B were approximately the same, while that of trees under C was larger, again, the difference being highly significant. The yields, in terms of pods per

360 trees, obtained to date are given in the following table:

Date	Treatment		
	A. Control	B. Flowers removed to Jan. 1957	C. Flowers removed to Jan. 1958
Sept.-Dec. 1955	96	-	-
Jan. -Dec. 1956	2468	-	-
Jan. -Dec. 1957	3042	3567	-
Jan. -Dec. 1958	4242	3854	5988
Total	9848	7421	5988

Subsequent years will show whether the larger girth in treatment C will be maintained, or will prove a short-term effect as in treatment B. In neither 1957 nor 1958 were the harvests for treatments A and B significantly different from each other, and thus no evidence has been obtained so far of a stimulatory effect on yield due to the limitation of early bearing.

Gibberellic acid on cuttings

Repeated leaf applications of gibberellic acid at a concentration of 10 and 50 µg./ml, have stimulated shoot growth of cuttings, although to a much smaller extent than that of seedlings (cf. Quarterly Report No.49, p.17). The higher concentration stimulated growth more than did the lower, but proved toxic to some of cuttings, indicating that a considerable amount must have been absorbed. It is possible to conclude tentatively that stimulation of growth in cuttings requires a much higher concentration of gibberellic acid at the meristem than is required by seedlings. The leaves in the 50 µg. treatment were smaller and narrower than those in the 10 µg. treatment, both with seedlings and cuttings.

CHEMISTRY DIVISION

SOIL FERTILITY

Field experiments

The 1958-59 harvest was finished on 31st March and the results have not yet been analysed. However, there are indications that a pattern of responses to major nutrients is beginning to emerge. In Ashanti responses to nitrogen and phosphorus have been obtained at four sites. Responses to phosphorus at W.A.C.R.I. and Apedwa and to potassium at Bunso

have been recorded. The final yields of the Shade and Manurial Trial at W.A.C.R.I. (see Quarterly Report No.49, p.17) are given below.

Treatment	Yield (lb. dry cocoa/acre)
Shade/No Fertilizer	958
Shade/Fertilizer	1,211
No Shade/No Fertilizer	2,348
No Shade/Fertilizer	3,091

The copper nutritional experiment on the Old Station, W.A.C.R.I. and the trace element experiment at Adonkwanta (Quarterly Report No.49, p.18) have not revealed any significant responses but are being continued.

COCOA PREPARATION AND QUALITY

During the main crop a large amount of information has been gathered about the behaviour of cocoa when fermented by the 'tray' method. Work on the fermentation of small heaps of cocoa under conditions of uniform external temperature have continued. The experiments to find out how far the heat produced when cocoa beans are heaped is dependent on microbial activity in the pulp have been completed.

I B A D A N S U B - S T A T I O N

PATHOLOGY SECTION

VIRUS RESEARCH

The interaction between cacao swollen shoot virus and the dieback fungus Calonectria rigidiuscula (Berk. & Br.) Sacc. on the growth of cacao

Recent observations in the field suggest that capsids and subsequent attack by the dieback fungus Calonectria rigidiuscula (Berk. & Br.) Sacc. are particularly severe on trees infected with cacao swollen shoot virus. This possibility of an interaction between virus and fungus is now being investigated in laboratory experiments.

In the first of these, plants were infected as beans with different isolates of virus from Western Nigeria. After three months the plants infected with the most virulent strains

were severely stunted compared with the healthy controls, which also made slightly better growth than plants infected with other strains. Each series of plants was then divided at random into five groups, which received 9, 6, 3, 1 or 0 inoculations with C. rigidiuscula. This was applied as a spore and mycelial suspension with a cold, sterile needle. The inoculations were made in a ring at a constant height above soil level and followed damage caused by a prior piercing with a needle taken from boiling water.

The inoculations and subsequent growth of the dieback fungus made obvious stem lesions and considerable portions of the xylem tissue were killed. Nevertheless, they had no detectable effect on the growth of the plants without virus or of those infected with the mildest strains. In each group the plants grew vigorously and rapidly developed new vascular tissue which was adequate to sustain growth even under completely exposed conditions. Plants infected with the most virulent strains behaved in the same way when only 1 or 3 inoculations were made, but 6 and 9 inoculations caused die-back symptoms to develop in a proportion of the plants (Table I).

TABLE I

The number of virus infected and healthy plants showing die-back symptoms after different numbers of needle inoculations with C. rigidiuscula+

Virus isolate	Mean stem diameter at inoculation (cm)	No. of inoculations with C. rigidiuscula					
		0	1	3	6	9	Total
Severe Ikire	0.43	0/5	0/5	0/5	5/5	4/5	9/25
Abaku	0.55	0/4	0/4	0/4	0/4	2/4	2/20
Ilaro	0.65	0/5	0/5	0/5	2/5	1/5	3/25
Severe Koroboto	0.65	0/4	0/4	0/4	0/4	1/4	1/20
Mild Koroboto	0.76	0/4	0/4	0/4	0/4	0/4	0/20
Healthy	0.88	0/5	0/5	0/5	0/5	0/5	0/25
Total		0/27	0/27	0/27	7/27	8/27	15/135

+ The fractions in the table indicate the number of plants showing dieback symptoms out of the total number inoculated.

This preliminary experiment with seedlings and using artificial inoculations has limited relevance to the field situation. Nevertheless the results suggest that trees affected by the most virulent strains of virus are likely to suffer more severely than healthy ones from the effects of comparable levels of capsid attack. Furthermore, it seems that virus-infected trees will be subject to

damaging levels of capsid attack for a greater part of the year than healthy trees, which may withstand all but the heaviest infestations. In each instance virus-infected trees are more likely to deteriorate than healthy ones and may even be killed if the cycle of deterioration continues unchecked.

The effects of virus on growth and yield

The 1958-59 yield records are now available for the observation plot at Koroboto. This plot is heavily infected with swollen shoot disease, but with few exceptions the trees continue to make good growth in the absence of capsids, which have been virtually eliminated by routine spraying. The latest yields are the highest which have been recorded since observations started in 1954. An average of 24 pods were harvested from each tree compared with 16 the previous year and 15 in the 1954-1955 crop season. The infected trees continue to outyield the symptomless ones as they have done in previous years and yields are not correlated with the length of time the trees have been infected with virus. Clearly the virus at Koroboto has less effect than other factors on growth and yield.

The Koroboto results are not unique and similar ones have been obtained elsewhere in Ibadan Province and at Iweke near Ilaro. Indeed, there is no evidence to show that viruses in Nigeria will kill trees which are not seriously infested with capsids or where these insects are controlled. The trees in several additional outbreaks were sprayed for the first time in 1958 and are now showing a striking recovery, similar to that noted at Koroboto. There is no obvious difference in behaviour between virus-infected and symptomless trees; both have made good growth even during the recent severe dry season.

The situation in Nigeria is similar to that in Trinidad but quite different from that in Ghana. There, screened trees in good condition died after inoculation with virulent virus from the New Juaben area (Posnette, unpublished information). Other trees died in large scale inoculation experiments in which capsids were not considered to be a complicating factor. It seems that the swollen shoot viruses in West Africa occur in numerous forms which differ very widely in pathogenicity as in other properties. The mildest strains have a barely detectable effect on growth and yield and differ markedly from the most virulent strains which are usually lethal. Other viruses, including many of the ones occurring in Nigeria, affect growth and yield but have lethal effects only

where conditions are unsatisfactory and particularly where capsids are numerous. The relative distribution of mild, severe and lethal virus strains in Nigeria and Ghana requires further study and probably accounts for the apparent inconsistencies now being obtained on the effects of virus on growth and yield.

For uniformity it is suggested that the term mild should be restricted to virus isolates which cause very limited symptoms and have a barely detectable effect on the growth of seedlings. Trees infected with mild viruses never show swellings, are frequently symptomless or show only transient red vein banding. Their yield is not obviously affected and they do not die. By comparison, the virulent viruses cause conspicuous swellings and leaf symptoms on seedlings and on trees. They obviously stunt growth and infected trees frequently die when they are also attacked by capsids. Pod mottle symptoms are usually found and the flush leaves are frequently distorted and fall before expanding. The surviving leaves show severe interveinal chlorosis soon after infection and more limited vein banding symptoms at a later stage.

Lethal viruses are apparently absent from Nigeria, but in Ghana have rapid and drastic effects on seedlings and trees which may be killed even under the most favourable conditions. Outbreaks spread rapidly in the field and patches of dead and dying trees are surrounded by recently infected trees which show conspicuous swellings and leaf symptoms and often a conspicuous chlorosis and stunting. Other categories could be suggested but an examination of most outbreaks usually reveals whether the typical virus occurring there is mild, intermediate, virulent or lethal in its effects and further subdivision is not justified.

STUDIES ON "DIE-BACK" OF CACAO

The effects of varying factors on the spread of lesions, made by a sterile needle and also by a needle contaminated with spores of Fusarium decemcellulare Brick (Calonectria rigidiuscula Berk. & Br.) Sacc. have been studied in the stems of Amelonado and Amazon cacao seedlings of various ages. The following factors were studied under shade and in full sunlight:- three degrees of watering; two degrees of defoliation; two levels of nitrogen, phosphate, and potassium salts; increased pH of the soil; the presence of sawdust in the oil promoting nitrogen deficiency; and the presence and absence of viruses. Full analysis of these results will be made later. It is apparent that certain factors can significantly influence the growth rate of the infected

lesions but none have any effect on the "sterile" lesions. The "sterile" lesions are frequently infected with various fungi, including Botryodiplodia theobromae and Phomopsis sp. and occasionally by C. rigidiuscula, the spores of which are commonly found on the bark of cacao trees.

In mature Amelonado trees, the effects of the presence and absence of shade, root pruning, defoliation, ring-barking and fertilizers on the spread of Calonectria lesions were also examined. Lesions resulting from artificial inoculations grew much faster than was expected and merged with each other, thus confusing the results which are not therefore suitable for analysis. The effect of the presence and absence of virus in trees has been studied and the results will be analysed shortly.

A comparison is being made of the growth rate of C. rigidiuscula lesions in various tissues to compare the influence of fan, chupon and seedling tissue, and the age and size of the branch into which the inoculation is made. The apparent variation between growth in nodes, as compared with internodes, is also being studied.

A multiple inoculation technique has been developed that gives, under experimental conditions, the symptoms of die-back, as found in the field. This technique has proved to be of limited application with seedlings of up to eighteen months of age but is very successful on mature trees. A ring of inoculation points is made around a twig and infected with C. rigidiuscula. In the field the amount of die-back induced under varying conditions is being studied and the subsequent development of this induced die-back will be observed.

It has been observed in the field that C. rigidiuscula can enter the tree via capsid lesions, mechanical injuries, and shothole borer damage and it has also been shown experimentally that the fungus can live as a saprophyte on dead wood and when this is in contact with healthy wood it may subsequently invade the latter as a parasite.

ENTOMOLOGY SECTION

SHOT-HOLE BORERS

The number of seedlings attacked by shot-hole borers (Scolytidae) in the two experiments at Moor Plantation and Akure continued to increase during the quarter.

At Moor Plantation, the earlier indications that the urea - formaldehyde lacquers incorporating Dieldrin might give a partial control of these pests were found to be misleading. The attack was evenly distributed between all treatments with 84.5 per cent of seedlings infested. Fifty-two per cent of all seedlings had died by the end of March and a further 28 per cent were showing severe wilt, the majority of the latter having at least the upper portion of the stem dead.

At Akure the results on the unwatered plots were similar, though both the incidence of borers and of wilting and death was lower, being approximately 60 per cent bored and 70 per cent wilted or dead. On the plots on which each plant received one gallon of water twice a week during the dry season borer incidence was not reduced, but the majority of plants continued to thrive and grow despite this attack, and only about 2.5 per cent of the seedlings suffered from drought symptoms. The analysis of the results of this trial has been complicated by two extraneous factors, namely attacks by termites on certain areas within the trial and by the cutting of a trace for a pipeline through one of the two blocks in which it was laid down, with consequent destruction of a number of seedlings. A more accurate statistical assessment of the results may be possible when the records have been abstracted in detail and the compensatory adjustments made for missing stands. This will then be reported elsewhere. The trial was brought to a close at the end of March after the onset of the rains.

OTHER INSECT PESTS OF SEEDLINGS

The Anthribid and weevil species reported a year ago as attacking seedlings in their first and second dry seasons in the field have been identified by the staff of the Commonwealth Institute of Entomology as Phloeobius sp. and Coryssopus sp. respectively. The former has again been recorded from Ondo Province and from Abeokuta Province, from both of which localized but severe damage was reported in new plantings under moderate to heavy shade. The larvae of this species enter the stem at ground level and bore in a long spiral for a distance of one to three inches up into the stem or down into the root, thereafter turning to form another spiral boring in the opposite direction and finally a further spiral back to ground level, at which pupation takes place within the stem. Affected seedlings usually die suddenly during the last stages of larval activity and the stem is so weakened by the attack that the dead plants are

easily knocked over. Normally only one larva is found in a seedling, though a double infestation has been seen. A group of hymenopterous parasites have been reared from a single pupa.

Although this species was not uncommon at Apoje in the dry season of 1957-58, it was not found during two visits made recently. It is possible that applications of insecticides, made in the hope of controlling shot-hole borers, may have contributed to this, but it should be remembered that the new plantings are in a different part of the plantation and in view of the local distribution of the pest, may have escaped attack for this reason. Coryssopus sp. has not been found again.

Damage by Tettigioniidae

At Akure over 40 seedlings were found, into the stems of which, a long horned grasshopper had inserted its eggs. These were placed in five to seven parallel plates per seedling each containing up to 15 eggs. The incision was usually made a few inches above ground level and penetrated well beyond the middle of the seedling. At the outermost end of each egg there was a ribbon of oothecal material which protruded from the stem. Over 6 per cent of the seedlings in one block of 600 in the Shot-Hole Borer Control Trial were attacked in this way, but the plants did not seem to suffer unduly as a result. Several hymenoptrous parasites and ten nymphs were obtained from four egg masses brought into the laboratory, but the nymphs died on the second or third day after hatching. Adults have not been observed in the act of ovipositing.

AGRONOMY SECTION

MOOR PLANTATION

Rainfall

Month	Rainfall (in.)	
	1959	11-year mean
January	0.03	0.33
February	0.68	0.95
March	2.40	3.59
Total	3.11	4.87

Plots Y1 and C6 at Moor Plantation

Galls on flowering cushions were found on trees of ICS 1, ICS 9 and ICS 7 cacao in plot C6. Large galls up to 2 in. in diameter were found in discrete groups of five and six trees of ICS 1 and ICS 9 respectively. Apparently abnormal cushions were found on some forty other trees of these two types between and around the affected groups. Attempts have been made to isolate fungi and bacteria from affected cushions, but without success. A number of young, vigorous Amelonado trees have been grafted with cushions from affected trees in an attempt to transmit the condition. Some galled trees in plot C6 have been pollarded, and subsequent new growth will be inspected regularly. Development of the abnormal flowering cushions will be observed on the remaining trees. Similar galls have also been observed on mature Amazon cacao trees at I.N.A. farm near Ibadan.

AGODI CACAO EXPERIMENTAL FARM

Fertilizer trial on mature peasant cacao

The first year's post-treatment harvest on the fertilizer trial described in Quarterly Report 50 has been completed. Covariance analysis of the yield data revealed no significant responses, though there is an indication that the NP treatment is depressing yield under the heavy shade conditions of this experiment.

Nursery Trial (See Quarterly Report No. 52)

Growth of the seedlings in this experiment has been satisfactory. Fertilizer is applied in solution to the pots at the following rates:-

N	0.5 gm. per plant per month.		As urea.
P	0.2 gm. " " " "	}	As potassium phosphate.
K	0.25 gm. " " " "	}	
Mg	0.1 gm. " " " "		As magnesium sulphate.

Height measurements indicate that closely packed plants are taller than the widely spaced ones. No beneficial effect of fertilizer has been noted. There are interesting differences between the shade treatments, however. Growth has been greatest under the light shade treatment, though decreasing light intensity has reduced leaf production as shown in the following table:

	No Shade	Light Shade	Heavy Shade
Mean height per plant (cm.)	20.26	25.09	22.95
Mean leaf no. per plant	12.82	11.47	9.37

Visual observations indicate that with increasing light intensity, leaf size is decreased, thus the total leaf area per plant in the three shade treatments may not differ greatly. This will be further investigated.

An experiment has been started at Agodi to determine the effect of virus on the yield of Amelonado cacao trees. The experiment consists of eight randomized blocks of the following three treatments:

(a) healthy control
(b) inoculation with mild virus.
(c) inoculation with severe virus.

Four replications contain mild and severe strains of virus from Koroboto, the other four replications contain Ikire mild strain and Offa Igbo severe strain. Inoculations were carried out in February by patch grafting. Symptom records will be taken at monthly intervals on inoculated trees, and trees surrounding virus infected plots. Pre-treatment yield data are available.

Koroboto Seedling Experiments

In neither experiment has a beneficial effect of fertilizer been noted. In the second experiment early growth in the heavy shade treatment was significantly greater than that under light shade (P = .01). In both experiments severe and mild viruses are significantly suppressing growth. After eight months in the field, the difference in growth between virus inoculated plants and healthy controls, though significant, is surprisingly small. The following data from the first experiment illustrate this

	Healthy Controls	Mild Virus	Severe Virus
Mean height per plant (cm.)	101.34	94.49	87.61 (Mar. 1959)
Mean no. of leaves per plant	21.03	19.33	17.47 (Mar. 1959)

The mean monthly height increment per plant is 8.35 cm. These results suggest that there is quite a high degree of tolerance of virus infection in this unselected Amazon population. Grading the seedlings for uniformity before planting has resulted in extremely low coefficients of variability in both experiments, of the order of 5 per cent. It will be interesting to follow the changes in the coefficients throughout the life of the trial. Analysis of the data is proceeding and will be reported fully elsewhere.

WEST AFRICAN FUNGICIDE RESEARCH UNIT

The physical assessment of the laboratory sprayer for application of fungicide to individual pods has continued. It has become obvious that if the highest uniformity of deposits is to be obtained particular care to control angle of nozzle, air pressure and period of application will be necessary. Modification to the apparatus to achieve this control is being made. Some comparison of the physical properties of fungicides has also been carried out.

CTQ.